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EXPERIMENTAL INVESTIGATION OF AERODYNAMIC CHARACTERISTICS OF EL--ETC(U)
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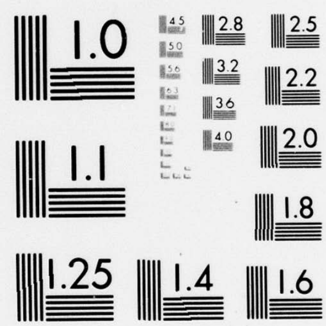

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EXPERIMENTAL INVESTIGATION OF AERODYNAMIC CHARACTERISTICS OF ELASTIC MODELS IN SUPERSONIC WIND TUNNEL

By

V. Ya. Belyayev, L. G. Totiashvili, et al

FOREIGN TECHNOLOGY DIVISION

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EXPERIMENTAL INVESTIGATION OF AERODYNAMIC CHARACTERISTICS OF ELASTIC MODELS IN SUPERSONIC WIND TUNNEL

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Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

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EXPERIMENTAL INVESTIGATION OF AERODYNAMIC CHARACTERISTICS OF ELASTIC MODELS IN SUPERSONIC WIND TUNNEL

V. Ya. Belyayev, L. G. Totiashvili, N. N. Tyunin, M. V. Ushakov

With the advent of supersonic airplanes with thin wings of small aspect ratio and relatively high flexibility there has been growing interest in the effect of elastic deformations of the structure on the characteristics of stability and controllability.

Along with development of theoretical methods of calculating and conducting flight tests, there is also a great deal of interest in methods of determining the aerodynamic characteristics of an aircraft by conducting experimental studies on an elastic model of it in a wind tunnel.

1. Modeling conditions. The greatest difficulty in conducting similarity experiments is encountered in satisfying the conditions of similarity, since, in addition to aerodynamic similarity, there must

also be similarity with respect to the mass and elastic characteristics. Similarity with respect to the elastic characteristics presumes equality between the normalized functions of the effect for nature and the model and the satisfaction of certain conditions for characteristic values of the functions of the effect.

If we assume that the functions of the slant effect, which describe the change in the local angle of attack, have decisive influence, then the last condition is reduced to satisfaction of the equality [1]:

$$C_M^{\alpha y} = C_H^{\alpha y} \frac{q_H}{q_M} \cdot \frac{1}{\mu^2} \qquad (1)$$

where $C^{\alpha y}$ is the characteristic value of the function of the effect, q - the dynamic head, μ - geometric scale of the model, subscripts "M" and "H" refer to the model and to reality, respectively.

Further simplification in the problem of modeling for a wing of small aspect ratio is achieved by replacing it with a beam of variable rigidity over the chord, while rigidity over the span is assumed to be infinitely great [2].

In this case the conditions of similarity are reduced to an identical distribution of normalized rigidity over the chord and

satisfaction of the last equality for characteristic rigidity values for the model and reality

$$(EJ)_{M} = (EJ)_{H} \frac{q_{M}}{q_{H}} N^{4}, \qquad (2)$$

where EJ is the flexural rigidity of the beam. Since the main purpose of the study was to master an experimental technique for supersonic wind tunnels and a technology for preparing elastic models, the conditions of similarity were satisfied only approximately. However, for further refinement of the elastic characteristics of the models and to use the calculation method, such effect functions as $C^{\alpha y}$ were measured.

2. Structure of studied models and method of determining function of effect.

Figure 1 depicts a model consisting of fuselage 1 with fairing 3 and wing 2. To prepare nonrigid fuselage (1) a thin-walled tube 26 mm in diameter with a wall thickness of 0.5 mm was used. The front portion of the tube has interior conical opening 4 for attachment to internal balances. Threaded openings 8 serve as a point of attachment for wing 2 and fuselage 1. Vertical grooves divide the tube into rings, whose lower portion is soldered to plate 7, which functions as the main elastic element of the fuselage. Struts 6 are attached to

the rings of fuselage 1 by glue BF-2 and fill the lateral gaps.

The frame of the fuselage thus prepared is covered inside and out with a layer of compound SKM 5 forming a smooth elastic skin which maintains is properties virtually unchanged within a temperature range of from -30° to +100°C, while supporting the load of the inside-outside pressure difference in a supersonic flow. The combination of fuselage 1 and wing 2, made of textolite with $E = 10^5$ kg/cm^2, shown in Fig. 1, will henceforth be called "Model 2". "Model 1" differs structurally from "Model 2", since it has a rigid fuselage and wing of polystyrol with $E = 0.3 \cdot 10^5$ kg/cm^2. The rigid model is used as the base and consists of a rigid fuselage and rigid wing.

Models 1 and 2 were used to determine the functions of the effect. These were determined on the special stand shown in Fig. 2, which consists of base 1 with studied model 3 attached to the pedestal. A grid of mutually perpendicular lines with a pitch of 20 mm, whose intersection determines the number of points (34-35) has been applied to the wings. Their numbering system is given in Fig. 3.

Mirror 4 in Fig. 2 is attached to a selected point on the studied model. The beam of light from light source 5 is directed at the mirror, reflected from it, and falls on screen 6 with the scale grid.

Load-bearing brackets 2 are placed at all points in succession, including the studied point. The local angle of turn in the wing at the given point is determined by the magnitude of reference difference in the beam on the screen, obtained with and without the load. In the measurements the mean square error was ±6%. The measuring results for models 1 and 2 are shown in Tables 1 and 2[1], respectively.

[FOOTNOTE [1]. See appendix. ENDFOOTNOTE].

To obtain angular shifts it is sufficient to multiply the reduced values by coefficient $K_1 = 0.00609$ deg/[original illegible].

3. Results of experimental studies. In a supersonic stream the models were tested at angle of attack of 0-3° and numbers M = 1.75-2.5 with a special catch mechanism, whose function was to restrain the model wing as it passed through the tunnel shock wave. Without the catch mechanism the studied models would not have withstood the starting loads and would have been destroyed. Obtained as a result of static tunnel tests were the values $C_y(\alpha)$ and $\bar{X}_F(\alpha)$, shown in Fig. 4 for M = 2. Analysis of the obtained results shows that agreement between C_y and the value for the rigid model is characteristic for model 1.

There is a tendency toward a backward shift of 4-5% for the focus. This type of change in C_y and $\bar{x}_F$ is explained by the two-point attachment of the wing to the fuselage, which causes a S-shaped deformation of the wing, affecting the moment characteristics.

For model 2 there is a significant drop in C_y (to 25% as compared to the rigid model), and the focus moves forward by 4%. This fact is explained by the different type of model deformation, which is similar to the deformation of a cantilever beam of variable rigidity. This causes a change in local angles of attack in the more loaded tail section of the model. Analogous data were obtained at the remaining M numbers and for other models.

Calculated from the known values of the functions of the effect of the model were its aerodynamic characteristics. It was assumed that the distribution of aerodynamic weight over the deformed wing is described by the "piston" theory.

In this case the problem was reduced to solving the integral equation

$$\Delta\alpha(x,y) = \iint_S C(x,y,\xi,z)\cdot P(\xi,z)\cdot dS \qquad (3)$$

where

$$P(\xi,z) = \frac{4}{M} q[\alpha + \Delta\alpha(\xi,z)].$$

The solution to (3) was determined by the method of successive approximations. The results of calculations for models 1 and 2 are represented by a dot-dash line in Fig. 4. The experiment and calculation show that:

a) For the studied range of problems modeling by such effect functions as C_y^{α} is sufficient;

b) elastic deformations may lead to substantial changes in the aerodynamic characteristics of an aircraft;

c) further development of methods for studying elastic models in wind tunnels is recommended.

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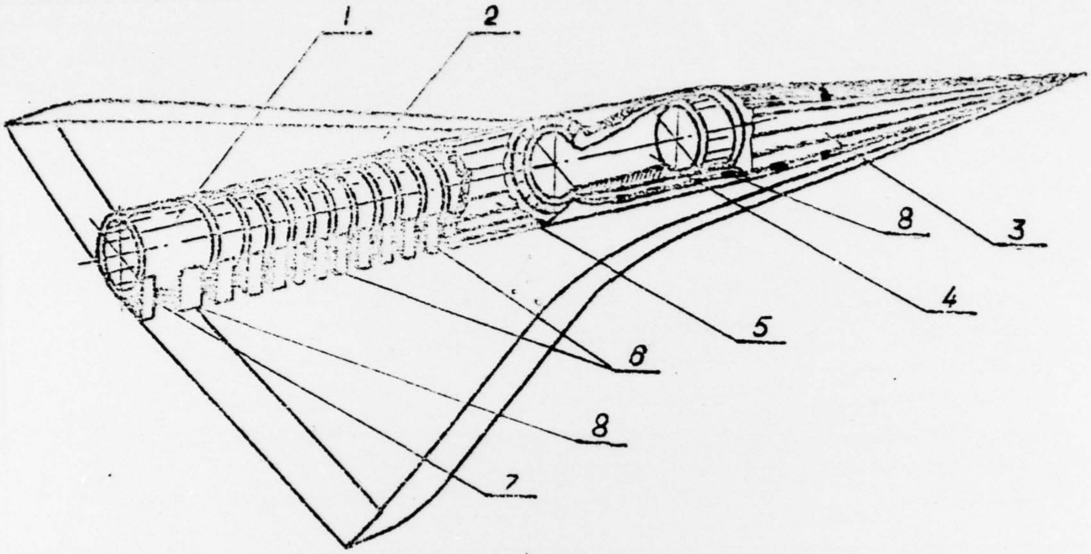


Fig. 1.

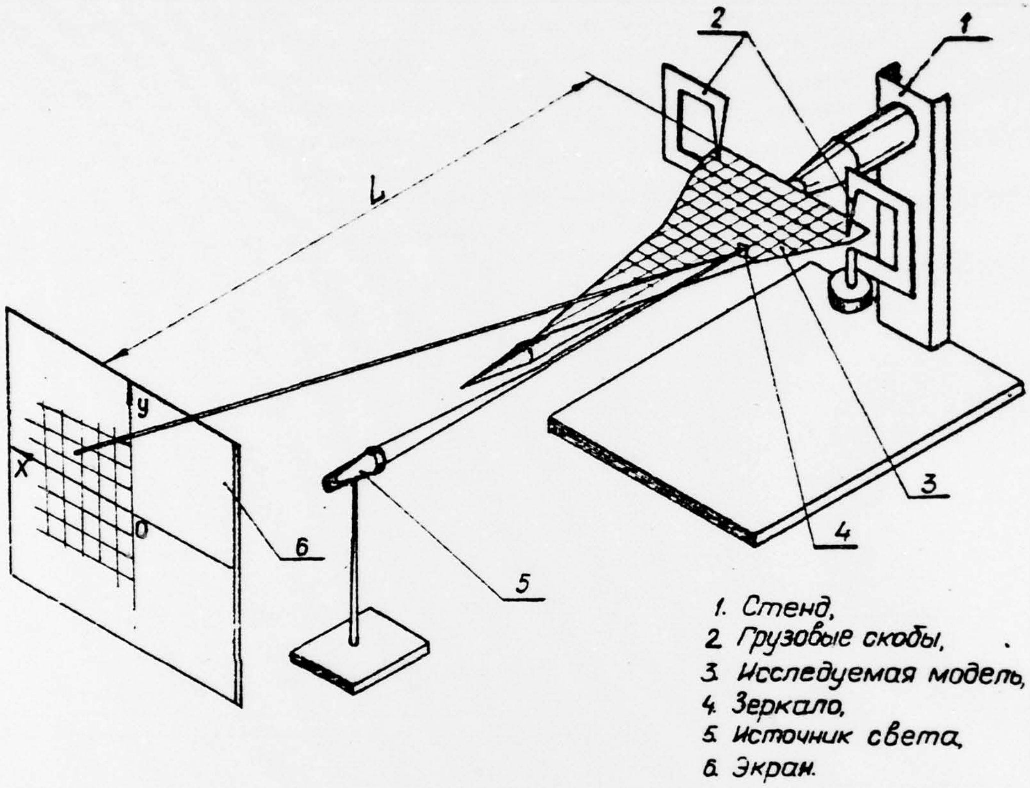
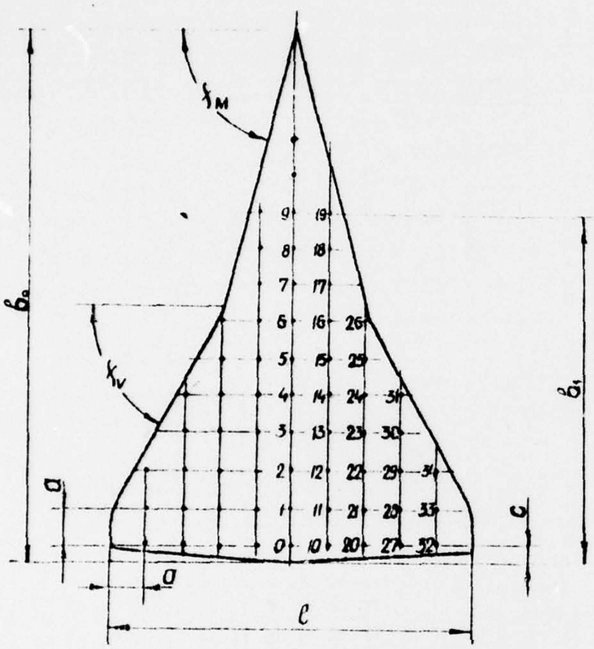


Fig. 2. Key: 1) Stand. 2) Load-bearing brackets. 3) Studied model. 4) Mirror. 5) Light source. 6) screen.



b_0	b_1	l	a	c	$\chi_м$ 1)	χ_v 1)
м	м	м	м	м	град	град
0,285	0,190	0,200	0,020	0,008	77	57

Fig. 3. Key: 1) deg.

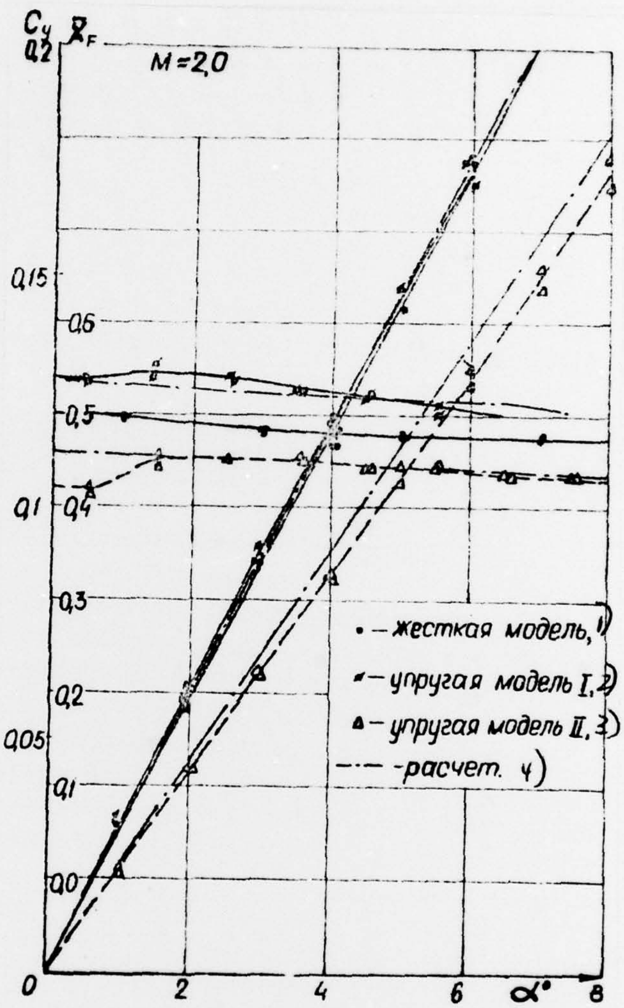


Fig. 4. Key: 1) rigid model. 2) elastic model I. 3) elastic model II. 4) calculation.

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